The Association

of

Engineering and Shipbuilding Draughtsmen.

Reinforced Concrete Design Data.

By ANTHONY d'O SMITH,

Member American Society of Civil Engineers; American Concrete Institute.

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Member American Society of Civil Engineers; American Concrete Institute.

FOREWORD.

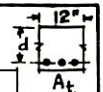
THE object of this booklet is to place before the busy engineers and draughtsmen, in as concise a form as possible, practical information in regard to reinforced concrete construction in the hope that the booklet will help to promote the greater use of the reinforced concrete building framework.

The tables as presented cover a wide range of working stresses and include those used by a majority of engineers. They should be particularly helpful for establishing sizes and for preliminary estimating and costing.

For the engineer who may already have a complete set of curves or tables, this booklet offers a quick and independent check which is very valuable in ensuring accuracy of results.

The table on compression reinforcement treats the problem of calculating the tensile and compressive reinforcement in a double reinforced beam in a very simple form, while the American method given is fully in accordance with tests carried out in the U.S.A. and is once again contained in the most recent American Concrete Institute Building Code (A.C.I. 318-56).

BALANCED STEEL. C = 1000 p.s.i m = 15.



BENDING MOMENT (M) & STEEL AREA (A_t) PER FOOT OF WIDTH.

EFFECTIVE DEPTH: d. inches.	t = 18000		t = 20000		t = 27000		t = 30000		t = 33000	
	M 1000 ft lb	A_t sq in	M. 1000 ft lb.	A_t sq. in.	M. 1000 ft lb.	A_t sq. in.	M. 1000 ft lb.	A_t sq. in.	M 1000 ft lb.	A_t sq. in.
2	·77	·30	·74	·26	·63	·16	·59	·13	·56	·11
2¼	·98	·34	·93	·29	·80	·18	·75	·15	·70	·13
2½	1·21	·38	1·15	·32	·98	·20	·92	·17	·87	·14
2¾	1·46	·42	1·39	·35	1·19	·22	1·12	·18	1·05	·16
3	1·74	·45	1·66	·39	1·41	·24	1·33	·20	1·25	·17
3¼	2·04	·49	1·95	·42	1·66	·26	1·57	·22	1·47	·19
3½	2·37	·53	2·26	·45	1·93	·28	1·82	·23	1·71	·20
3¾	2·72	·57	2·59	·48	2·21	·30	2·08	·25	1·96	·22
4	3·09	·60	2·94	·51	2·51	·32	2·37	·27	2·23	·23
4¼	3·49	·64	3·33	·55	2·84	·34	2·68	·29	2·52	·24
4½	3·91	·68	3·73	·58	3·19	·36	3·00	·30	2·82	·26
4¾	4·36	·72	4·16	·61	3·55	·38	3·34	·32	3·14	·27
5	4·8	·76	4·6	·64	3·9	·40	3·7	·34	3·5	·28
5¼	5·3	·79	5·1	·67	4·3	·42	4·1	·35	3·8	·30
5½	5·8	·83	5·5	·70	4·7	·44	4·4	·37	4·2	·31
5¾	6·4	·87	6·1	·74	5·2	·46	4·9	·39	4·6	·32
6	6·9	·91	6·6	·77	5·7	·48	5·3	·40	5·0	·34
6¼	7·5	·95	7·2	·80	6·1	·50	5·8	·42	5·4	·35
6½	8·1	·98	7·7	·83	6·6	·52	6·2	·44	5·8	·37
6¾	8·8	1·02	8·4	·87	7·2	·54	6·8	·45	6·3	·38
7	9·5	1·06	9·0	·90	7·7	·56	7·2	·47	6·8	·39
7½	10·8	1·14	10·3	·96	8·8	·60	8·3	·50	7·8	·42
8	12·3	1·21	11·8	1·03	10·0	·64	9·5	·54	8·9	·45
8½	13·9	1·29	13·2	1·09	11·3	·67	10·7	·57	10·0	·48
9	15·5	1·36	14·9	1·16	12·7	·71	12·0	·60	11·3	·51
9½	17·3	1·44	16·6	1·22	14·1	·75	13·3	·64	12·5	·54
10	19·3	1·52	18·4	1·28	15·7	·79	14·8	·67	13·9	·56
10½	21·2	1·59	20·2	1·34	17·2	·83	16·3	·71	15·3	·59
11	23·4	1·66	22·2	1·41	19·0	·87	17·9	·74	16·8	·62
11½	25·4	1·74	24·3	1·47	20·7	·91	19·5	·77	18·3	·65
12	27·8	1·82	26·5	1·54	22·6	·95	21·3	·81	20·0	·68
	Q = 193 r = ·0126		Q = 184 r = ·0107		Q = 157 r = ·0066		Q = 148 r = ·0056		Q = 139 r = ·0047	

RECTANGULAR BEAMS & SLABS.

BALANCED STEEL C = 1000 p.s.i. m = 15

BENDING MOMENT (M) & STEEL AREA (A_t) PER FOOT OF WIDTH.

EFFECTIVE DEPTH d inches.	t = 18000.		t = 20000.		t = 27000.		t = 30000		t = 33000.	
	M. 1000 ft.lb.	A_t sq.in	M. 1000 ft.lb	A_t sq.in.	M. 1000 ft.lb	A_t sq.in	M 1000 ft.lb	A_t sq.in.	M. 1000 ft.lb	A_t sq.in.
12½	30·1	1·89	28·7	1·60	24·5	·99	23·1	·84	21·6	·71
13	32·6	1·96	31·1	1·68	26·5	1·03	25·0	·87	23·5	·73
13½	35·1	2·04	33·5	1·74	28·5	1·07	26·9	·91	25·3	·76
14	37·8	2·12	36·0	1·80	30·8	1·11	29·0	·94	27·2	·79
14½	40·6	2·19	38·6	1·86	33·0	1·15	31·1	·97	29·2	·82
15	43·4	2·27	41·4	1·93	35·3	1·19	33·3	1·01	31·3	·85
15½	46·4	2·34	44·2	1·99	37·7	1·23	35·5	1·04	33·4	·88
16	49·4	2·42	47·1	2·05	40·2	1·27	37·9	1·08	35·6	·90
16½	52·5	2·49	50·0	2·11	42·7	1·31	40·2	1·11	37·8	·93
17	55·7	2·57	53·2	2·18	45·4	1·35	42·8	1·14	40·2	·96
17½	59·0	2·65	56·4	2·24	48·0	1·39	45·3	1·18	42·5	·99
18	62·5	2·72	59·6	2·31	50·8	1·43	48·0	1·21	45·0	1·02
18½	66·0	2·80	62·9	2·37	53·6	1·47	50·6	1·24	47·5	1·05
19	69·6	2·87	66·4	2·44	56·6	1·51	53·4	1·28	50·2	1·07
20	77·2	3·02	73·6	2·57	62·8	1·59	59·2	1·34	55·6	1·13
21	85·1	3·18	81·1	2·70	69·2	1·66	65·2	1·41	61·3	1·18
22	93·4	3·33	89·0	2·82	76·0	1·74	71·6	1·48	67·3	1·24
23	102	3·48	97·4	2·95	83·0	1·82	78·4	1·55	73·5	1·30
24	111	3·63	106	3·08	90·5	1·90	85·2	1·61	80·0	1·35
25	121	3·78	115	3·21	98·1	1·98	92·5	1·68	87·0	1·41
26	130	3·93	124	3·34	106	2·06	100	1·75	94·0	1·47
27	141	4·08	134	3·47	114	2·14	108	1·81	101	1·52
28	151	4·23	144	3·60	123	2·22	116	1·88	109	1·58
29	162	4·38	155	3·72	132	2·30	125	1·95	117	1·64
30	174	4·54	166	3·85	141	2·38	133	2·02	125	1·69
31	185	4·69	176	3·98	151	2·46	142	2·08	133	1·75
32	197	4·84	188	4·11	160	2·53	151	2·15	142	1·80
33	210	4·99	201	4·24	171	2·61	161	2·22	151	1·86
34	224	5·14	213	4·37	182	2·69	172	2·28	161	1·92
36	251	5·44	239	4·62	204	2·85	192	2·42	181	2·03

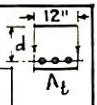
SECTION ONE FOOT WIDE.

M. ft. Kips. $= \frac{Qd^2}{1000}$ $\qquad A_t = rbd$

RECTANGULAR BEAMS & SLABS.

ADAPTED FROM THE REINFORCED CONCRETE DESIGN HANDBOOK OF THE AMERICAN CONCRETE INSTITUTE.

BALANCED STEEL. C = 1250 p.s.i. m = 15.



BENDING MOMENT (M) & STEEL AREA (A_t) PER FOOT OF WIDTH.

RECTANGULAR BEAMS & SLABS.

EFFECTIVE DEPTH d inches.	t = 18000		t = 20000		t = 27000		t = 30000		t = 33000.	
	M. 1000 ft.lb.	A_t sq.in.	M. 1000 ft.lb.	A_t sq.in.	M. 1000 ft.lb.	A_t sq.in.	M 1000 ft.lb.	A_t sq.in.	M 1000 ft.lb	A_t sq.in.
2	1·06	·42	1·01	·36	·88	·23	·84	·19	·80	·17
2¼	1·34	·48	1·28	·41	1·12	·26	1·06	·22	1·01	·19
2½	1·65	·53	1·58	·45	1·38	·29	1·31	·24	1·24	·21
2¾	2·00	·58	1·91	·50	1·67	·31	1·58	·26	1·51	·23
3	2·38	·64	2·28	·54	1·99	·34	1·88	·29	1·79	·25
3¼	2·80	·69	2·68	·59	2·34	·37	2·22	·31	2·11	·27
3½	3·23	·74	3·11	·63	2·72	·40	2·57	·34	2·45	·29
3¾	3·72	·80	3·57	·68	3·12	·43	2·95	·36	2·81	·31
4	4·22	·85	4·05	·72	3·54	·46	3·35	·38	3·18	·33
4¼	4·78	·90	4·58	·77	4·00	·48	3·77	·40	3·60	·35
4½	5·34	·96	5·12	·82	4·47	·51	4·24	·43	4·04	·37
4¾	5·96	1·01	5·72	·86	5·0	·54	4·72	·46	4·5	·39
5	6·6	1·06	6·3	·91	5·5	·57	5·2	·48	5·0	·41
5¼	7·3	1·12	7·0	·95	6·1	·60	5·8	·50	5·5	·43
5½	7·9	1·17	7·6	1·00	6·6	·63	6·3	·53	6·0	·45
5¾	8·7	1·22	8·4	1·04	7·3	·66	6·9	·55	6·6	·48
6	9·5	1·27	9·1	1·09	7·9	·68	7·5	·58	7·2	·50
6¼	10·3	1·33	9·9	1·13	8·6	·71	8·2	·60	7·8	·52
6½	11·1	1·38	10·6	1·18	9·3	·74	8·8	·63	8·3	·54
6¾	12·0	1·43	11·5	1·22	10·1	·77	9·5	·65	9·1	·56
7	12·9	1·49	12·4	1·27	10·8	·80	10·2	·67	9·7	·58
7½	14·8	1·60	14·2	1·36	12·4	·86	11·7	·72	11·1	·62
8	16·9	1·70	16·2	1·45	14·1	·91	13·4	·77	12·7	·66
8½	19·0	1·81	18·2	1·54	15·9	·97	15·0	·82	14·3	·70
9	21·4	1·91	20·4	1·63	17·9	1·03	16·9	·86	16·1	·75
9½	23·7	2·02	22·7	1·72	19·9	1·09	18·8	·91	17·9	·79
10	26·4	2·12	25·3	1·81	22·1	1·14	20·9	·96	19·9	·83
10½	29·0	2·23	27·8	1·90	24·3	1·20	23·0	1·01	21·9	·87
11	31·9	2·34	30·6	1·99	26·7	1·25	25·3	1·06	24·0	·91
11½	34·8	2·45	33·4	2·08	29·2	1·31	27·6	1·11	26·2	·95
12	38·0	2·55	36·4	2·17	31·8	1·37	30·1	1·15	28·6	·99
	Q = 264 r = ·0177		Q = 253 r = ·0151		Q = 221 r = ·0095		Q = 209 r = ·0080		Q = 199 r = ·0069	

BALANCED STEEL. $c = 1250$ p.s.i $m = 15$

BENDING MOMENT (M) & STEEL AREA (A_t) PER FOOT OF WIDTH.

EFFECTIVE DEPTH d inches.	t = 18000		t = 20000		t = 27000		t = 30000		t = 33000	
	M. 1000 ft. lb.	A_t sq. in.	M. 1000 ft. lb.	A_t sq. in.	M. 1000 ft. lb.	A_t sq. in.	M. 1000 ft. lb.	A_t sq. in.	M. 1000 ft. lb.	A_t sq. in.
12½	41·2	2·66	39·5	2·26	34·5	1·43	32·6	1·20	31·0	1·03
13	44·6	2·76	42·8	2·36	37·3	1·48	35·3	1·25	33·6	1·08
13½	48·0	2·87	46·0	2·45	40·2	1·54	38·0	1·30	36·2	1·12
14	51·7	2·97	49·6	2·54	43·3	1·60	41·0	1·34	39·0	1·16
14½	55·4	3·08	53·1	2·63	46·4	1·66	43·9	1·39	41·8	1·20
15	59·4	3·19	57·0	2·72	49·7	1·71	47·0	1·44	44·8	1·24
15½	63·4	3·30	60·7	2·81	53·0	1·77	50·2	1·49	47·7	1·28
16	67·6	3·40	64·8	2·90	56·6	1·82	53·5	1·54	50·9	1·32
16½	71·8	3·51	68·9	2·99	60·1	1·88	56·9	1·59	54·1	1·36
17	76·4	3·61	73·1	3·08	63·9	1·94	60·4	1·63	57·5	1·41
17½	80·9	3·72	77·5	3·17	67·6	2·00	64·0	1·68	60·9	1·45
18	85·5	3·82	82·0	3·26	71·6	2·05	67·8	1·73	64·5	1·49
18½	90·3	3·93	86·5	3·35	75·6	2·11	71·5	1·78	68·0	1·53
19	95·2	4·04	91·3	3·44	79·8	2·17	75·5	1·82	71·8	1·57
20	105·6	4·25	101·2	3·62	88·4	2·28	83·6	1·92	79·6	1·66
21	116	4·46	111	3·81	97·5	2·39	92·1	2·02	87·8	1·74
22	128	4·67	122	3·99	107	2·51	101	2·11	96·5	1·82
23	140	4·89	134	4·17	117	2·62	110	2·21	105	1·90
24	152	5·10	146	4·35	127	2·74	120	2·30	115	1·99
25	165	5·31	158	4·53	138	2·85	131	2·40	124	2·07
26	178	5·52	171	4·71	149	2·96	141	2·50	134	2·15
27	192	5·73	184	4·89	161	3·08	152	2·59	145	2·24
28	207	5·94	198	5·07	173	3·19	164	2·69	156	2·32
29	222	6·16	213	5·25	186	3·31	176	2·78	167	2·40
30	237	6·37	228	5·44	199	3·42	188	2·88	179	2·48
31	254	6·58	243	5·62	212	3·53	201	2·98	191	2·57
32	270	6·80	258	5·80	226	3·65	213	3·07	203	2·65
33	288	7·00	276	5·98	241	3·76	228	3·17	217	2·73
34	305	7·22	292	6·16	256	3·88	243	3·26	230	2·82
36	342	7·65	328	6·52	287	4·10	272	3·46	258	2·98

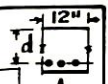
SECTION ONE FOOT WIDE.

M. ft. Kips = $\frac{Qd^2}{1000}$ $\qquad A_t = rbd$

RECTANGULAR BEAMS & SLABS.

ADAPTED FROM THE REINFORCED CONCRETE DESIGN HANDBOOK OF THE AMERICAN CONCRETE INSTITUTE

BALANCED STEEL. C = 1500 p. s. i. m = 15

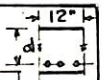


BENDING MOMENT (M) & STEEL AREA (A_t) PER FOOT OF WIDTH.

RECTANGULAR BEAMS & SLABS.

EFFECTIVE DEPTH: d inches.	t = 18000		t = 20000		t = 27000		t = 30000		t = 33000.	
	M. 1000 ft.lb.	A_t sq.in.	M. 1000 ft.lb.	A_t sq.in.	M. 1000 ft.lb.	A_t sq.in.	M. 1000 ft.lb.	A_t sq.in.	M. 1000 ft.lb.	A_t sq.in.
2	1·36	·56	1·31	·48	1·16	·30	1·10	·26	1·05	·22
2¼	1·72	·63	1·65	·53	1·47	·34	1·39	·29	1·33	·25
2½	2·12	·70	2·04	·59	1·81	·38	1·72	·32	1·65	·28
2¾	2·57	·77	2·47	·65	2·18	·42	2·08	·35	1·99	·30
3	3·06	·84	2·94	·71	2·60	·45	2·47	·39	2·37	·33
3¼	3·60	·90	3·46	·77	3·05	·49	2·92	·42	2·79	·36
3½	4·18	·97	4·02	·83	3·54	·53	3·38	·45	3·22	·39
3¾	4·78	1·04	4·60	·89	4·06	·57	3·88	·48	3·71	·41
4	5·44	1·11	5·24	·95	4·62	·60	4·40	·51	4·21	·44
4¼	6·14	1·18	5·91	1·01	5·22	·64	4·96	·55	4·75	·47
4½	6·88	1·25	6·62	1·07	5·86	·68	5·57	·58	5·32	·50
4¾	7·69	1·32	7·39	1·13	6·52	·72	6·21	·61	5·95	·52
5	8·5	1·39	8·17	1·19	7·2	·76	6·9	·64	6·6	·55
5¼	9·4	1·46	9·0	1·25	8·0	·79	7·6	·67	7·3	·58
5½	10·2	1·53	9·8	1·31	8·7	·84	8·2	·70	7·9	·61
5¾	11·2	1·60	10·8	1·37	9·6	·87	9·1	·74	8·7	·63
6	12·2	1·67	11·7	1·43	10·4	·91	9·9	·77	9·5	·66
6¼	13·3	1·74	12·8	1·49	11·3	·95	10·7	·80	10·3	·69
6½	14·3	1·81	13·7	1·55	12·1	·97	11·5	·83	11·0	·72
6¾	15·5	1·88	14·9	1·60	13·2	1·02	12·5	·87	12·0	·75
7	16·6	1·95	16·0	1·66	14·1	1·06	13·5	·90	12·9	·77
7½	19·0	2·09	18·3	1·78	16·2	1·14	15·4	·96	14·8	·83
8	21·8	2·23	20·9	1·90	18·5	1·21	17·6	1·03	16·8	·88
8½	24·5	2·37	23·5	2·02	20·8	1·29	19·8	1·09	18·9	·94
9	27·6	2·51	26·5	2·14	23·4	1·36	22·2	1·16	21·3	·99
9½	30·6	2·65	29·4	2·26	26·0	1·44	24·7	1·22	23·7	1·05
10	34·0	2·78	32·7	2·38	28·9	1·51	27·5	1·28	26·3	1·10
10½	37·4	2·92	36·0	2·50	31·8	1·59	30·2	1·34	28·9	1·16
11	41·2	3·06	39·6	2·61	35·0	1·66	33·3	1·41	31·8	1·21
11½	44·9	3·20	43·1	2·73	38·2	1·74	36·3	1·47	34·7	1·27
12	49·0	3·34	47·1	2·85	41·6	1·81	39·6	1·54	37·9	1·32
Q = 340 r = ·0232			Q = 327 r = ·0198		Q = 289 r = ·0126		Q = 275 r = ·0107		Q = 263 r = ·0092	

BALANCED STEEL $C = 1500$ p.s.i. $m = 15$.



BENDING MOMENT (M) & STEEL AREA (A_t) PER FOOT OF WIDTH.

EFFECTIVE DEPTH d inches.	t = 18000		t=20000		t= 27000		t= 30000		t= 33000	
	M. 1000 ft lb.	A_t sq. in.	M. 1000 ft lb.	A_t sq. in.	M. 1000 ft lb	A_t sq. in.	M 1000 ft lb	A_t sq. in.	M 1000 ft lb	A_t sq. in.
12½	53·0	3·48	51·0	2·97	45·1	1·89	42·9	1·60	41·0	1·38
13	57·5	3·62	55·3	3·09	48·9	1·97	46·5	1·67	44·4	1·44
13½	61·9	3·76	59·5	3·21	52·6	2·05	50·0	1·73	47·9	1·50
14	66·6	3·90	64·1	3·33	56·6	2·12	53·9	1·80	51·5	1·55
14½	71·4	4·04	68·6	3·45	60·6	2·20	57·8	1·86	55·3	1·61
15	76·5	4·18	73·5	3·56	65·0	2·27	61·9	1·93	59·1	1·66
15½	81·6	4·32	78·5	3·68	69·4	2·35	66·0	1·99	63·1	1·72
16	87·0	4·45	83·6	3·80	74·0	2·42	70·4	2·05	67·4	1·77
16½	92·5	4·59	89·0	3·92	78·6	2·50	74·8	2·11	71·5	1·83
17	98·2	4·73	94·5	4·04	83·5	2·57	79·5	2·18	76·0	1·88
17½	104·0	4·87	100·0	4·16	88·5	2·65	84·2	2·24	80·5	1·94
18	110·0	5·01	106·0	4·28	93·6	2·72	89·1	2·31	85·1	1·99
18½	116·0	5·15	112·0	4·40	98·9	2·80	94·0	2·37	90·0	2·05
19	122·7	5·29	118·0	4·51	104·3	2·87	99·4	2·44	94·9	2·10
20	136	5·57	130·8	4·75	115·6	3·02	110·0	2·57	105·2	2·21
21	150	5·85	144	4·99	127	3·18	121	2·70	116	2·32
22	164	6·12	158	5·23	140	3·33	133	2·82	127	2·43
23	180	6·40	173	5·46	153	3·48	145	2·95	139	2·54
24	196	6·68	188	5·70	166	3·63	158	3·08	151	2·65
25	212	6·96	204	5·94	181	3·78	172	3·21	164	2·76
26	230	7·24	221	6·18	195	3·93	186	3·34	178	2·87
27	248	7·52	238	6·42	210	4·08	200	3·47	192	2·98
28	266	7·80	256	6·65	226	4·23	216	3·60	206	3·09
29	286	8·07	275	6·89	243	4·38	231	3·72	221	3·20
30	306	8·35	294	7·13	260	4·54	247	3·85	237	3·31
31	326	8·63	314	7·37	277	4·69	264	3·98	252	3·42
32	347	8·91	334	7·60	295	4·84	281	4·11	268	3·53
33	371	9·18	356	7·84	315	4·99	300	4·24	287	3·64
34	394	9·47	378	8·08	334	5·14	319	4·37	305	3·75
36	442	10·02	424	8·55	374	5·44	356	4·62	342	3·97

RECTANGULAR BEAMS & SLABS.

ADAPTED FROM THE REINFORCED CONCRETE DESIGN HANDBOOK OF THE AMERICAN CONCRETE INSTITUTE.

SECTION ONE FOOT WIDE.

$M.ft.\ Kips. = \frac{Qd^2}{1000}$ $\qquad A_t = rbd$

BEAMS AND SLABS WITH COMPRESSIVE REINFORCEMENT

A beam reinforced for compression may be separated into two elements.
1. the beam with concrete alone in compression.
2. the beam with steel alone in compression.

The data sheet gives unit stresses in compressive reinforcement of beams & slabs for the permissible steel & concrete stresses shown using m = 15.

Example :-

Given $c = 1000$ p.s.i. $t = 27000$ p.s.i $b = 12"$ $d = 16"$ $a_1 = \cdot 881$ $Q = 157$

Bending moment $M = 550000$ in.lb.

1. The moment the section will carry with no compression reinforcement is $M_e = Qbd^2 = 157 \times 12 \times 16^2 = 480{,}000$ in.lb.

Tensile steel to balance the concrete is

$$A_t = \frac{M_e}{ta_1 d} = \frac{480000}{27000 \times \cdot 881 \times 16} = 1 \cdot 26 \text{ sq.in.}$$

2. By subtraction the moment to be cared for with compression steel is $M - M_e = 550{,}000 - 480{,}000 = 70{,}000$ in lb.

assume $d_c = 2"$ from data sheet; for $\frac{d_c}{d} = \frac{2}{16} = \cdot 12$

under the working stresses chosen the unit compressive stress $t_c = 9950$ p.s.i.

Therefore the area of compression steel required is

$$A_c = \frac{M - M_e}{t_c (d - d_c)} = \frac{70\,000}{9950(16-2)} = 0 \cdot 504 \text{ sq.in.}$$

Additional tensile steel required to resist the balance of moment

$$A_t = \frac{M - M_e}{t(d - d_c)} = \frac{70000}{27000 \times 14} = 0 \cdot 185 \text{ sq.in.}$$

The total tensile reinforcement is $A_t = 1 \cdot 26 + 0 \cdot 185 = 1 \cdot 445$ sq.in.

The above example shows the usual method of calculating compressive steel under the present C.P.114 (1948).

The American Concrete Institute Code ACI.318-51 Clause 706(b) states the effectiveness of compression reinforcement in resisting bending may be taken at twice the value indicated ($2t_c$) up to 18000 or 20000 p.s.i according to the tensile strength of the steel used.

The American Joint Committee 1940 also make a similar provision but in no case must a stress of ($2t_c$) greater than 16000 p.s.i. be allowed.

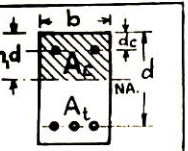
Using the American provisions in the example the compressive reinforcement is.

$$A_c = \frac{M - M_e}{2t_c (d - d_c)} = \frac{70\,000}{2 \times 9950 \times 14} = 0 \cdot 252 \text{ sq.in.}$$

BEAMS WITH COMPRESSION REINFORCEMENT.

UNIT COMPRESSIVE STRESSES.

t_c in 1000 lbs. per sq. in. for various d_c/d & concrete stresses c. $t_c = \frac{t}{1000} \times \frac{\left(n_1 - \frac{d_c}{d}\right)}{1 - n_1}$



C.P.114.(1948)

d_c/d	0·02	0·04	0·06	0·08	0·10	0·12	0·14	0·16	0·18	0·20	n_1
	t_c in KIPS. (1000 p.s.i. units.)										
c	t = 18,000 p.s.i. m = 15.										
1000	14·37	13·71	13·04	12·38	11·72	11·06	10·40	9·74	9·08	8·42	·455
1100	15·79	15·10	14·41	13·72	13·03	12·34	11·65	10·96	10·27	9·59	·478
1250		17·34	16·60	15·86	15·13	14·39	13·66	12·92	12·18	11·45	·511
1500						17·67	16·86	16·05	15·24	14·43	·556
	t = 20,000 p.s.i. m = 15.										
1000	14·32	13·62	12·92	12·22	11·52	10·82	10·12	9·42	8·72	8·02	·429
1100	15·83	15·10	14·37	13·64	12·91	12·17	11·44	10·71	9·98	9·25	·453
1250	17·98	17·21	16·43	15·66	14·88	14·11	13·33	12·56	11·78	11·01	·484
1500			19·91	19·06	18·22	17·37	16·52	15·67	14·82	13·97	·529
	t = 24,000 p.s.i. m = 15. (For Wind Stresses)										
1333	19·16	18·27	17·39	16·51	15·63	14·75	13·87	12·99	12·11	11·23	·455
	t = 27,000 p.s.i. m = 15.										
1000	14·15	13·31	12·47	11·63	10·79	9·95	9·11	8·27	7·43	6·59	·357
1100	15·61	14·74	13·87	13·00	12·13	11·26	10·39	9·52	8·65	7·78	·379
1250	17·92	17·01	16·09	15·17	14·26	13·34	12·42	11·50	10·59	9·67	·411
1333	19·02	18·08	17·14	16·20	15·26	14·32	13·38	12·44	11·50	10·56	·425
1500			19·57	18·58	17·59	16·60	15·60	14·61	13·62	12·63	·455
	t = 30,000 p.s.i. m = 15.										
1000	14·08	13·18	12·28	11·38	10·48	9·58	8·68	7·78	6·88	5·98	·333
1100	15·51	14·58	13·65	12·72	11·79	10·87	9·94	9·01	8·08	7·15	·354
1250	17·80	16·83	15·85	14·88	13·90	12·93	11·95	10·97	10·00	9·02	·385
1333	19·00	18·00	17·00	16·00	15·00	14·00	13·00	12·00	11·00	10·00	·400
1500			19·39	18·34	17·28	16·23	15·18	14·13	13·08	12·03	·429

SHEAR VALUE OF SINGLE VERTICAL STIRRUPS (TWO LEGS.) lb. per sq. in.

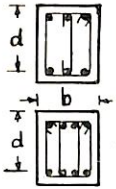
TABLE VALUES = $\frac{S}{a} = \frac{t_w A_w}{p}$

MAX. SPACING OF STIRRUPS $p \not> a$.
STIRRUPS AROUND COMPRESSION BARS $\not>$ 12× DIA. OF BAR.
DITTO. STEEL BEAM THEORY $\not>$ 8× DIA. OF BAR

CP. 114. (1948).

DIA. OF STIRRUP in.	STRESS LB. PER. SQ. IN. t_w	SPACING OF STIRRUPS (inches) = p.											
		2	2½	3	3½	4	4½	5	5½	6	6½	7	7½
3/16	18000	500	400	330	280	250	220	200	180	170	150	140	130
	20000	550	440	370	320	280	250	220	200	180	170	160	150
1/4	18000	880	710	590	510	440	390	350	320	290	270	250	240
	20000	980	790	650	560	490	440	390	360	330	300	280	260
5/16	18000	1380	1100	920	790	690	610	550	500	460	430	400	370
	20000	1530	1230	1020	880	770	680	610	560	510	470	440	410
3/8	18000	1990	1590	1330	1140	990	880	800	720	660	610	570	530
	20000	2210	1770	1470	1260	1110	980	880	800	740	680	630	590
7/16	18000	2710	2160	1800	1550	1350	1200	1080	980	900	830	770	720
	20000	3010	2410	2000	1720	1500	1340	1200	1090	1000	930	860	800
1/2	18000	3530	2830	2360	2020	1770	1570	1410	1290	1180	1090	1010	940
	20000	3930	3140	2620	2240	1960	1750	1570	1430	1310	1210	1120	1050
5/8	18000	5520	4420	3680	3160	2760	2450	2210	2010	1840	1700	1580	1470
	20000	6140	4910	4090	3510	3070	2730	2450	2230	2050	1890	1750	1640

WHERE. S = SHEAR FORCE AT THE SECTION IN. LBS.
A_w = CROSS SECTIONAL AREA OF A SINGLE STIRRUP (TWO LEGS) IN sq. in.
a = LEVER ARM (in)
p = PITCH OR SPACING BETWEEN ADJACENT STIRRUPS.
t_w = PERMISSIBLE STRESS = 18000 p.s.i FOR MILD STEEL. = 20000 p.s.i FOR COLD TWISTED STEEL

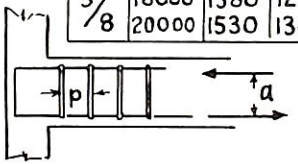


FOR 3 LEGS MULTIPLY TABLE VALUE BY 1·5

FOR 4 LEGS MULTIPLY TABLE VALUE BY 2

USE 3 OR 4 STIRRUP LEGS WHEN b EXCEEDS 1/2 OR 2/3 d

DIA. OF STIRRUP in.	STRESS LB. PER SQ. IN. t_ω	SPACING OF STIRRUPS (inches) = p.											
		8	9	10	10½	11	12	13	14	15	16	18	24
3/16	18000	120	110	100	95	90	83	76	72	66	63	56	41
	20000	140	120	110	105	100	92	85	80	74	69	62	46
1/4	18000	220	200	180	170	160	150	140	130	120	110	100	74
	20000	250	220	200	190	180	160	150	140	130	120	110	82
5/16	18000	350	310	280	260	250	230	210	200	180	170	150	120
	20000	380	340	310	290	280	260	240	220	210	190	170	130
3/8	18000	500	440	400	380	360	330	310	280	270	250	220	170
	20000	550	490	440	420	400	370	340	320	290	280	250	180
7/16	18000	680	600	540	510	490	450	420	390	360	340	300	230
	20000	750	670	600	570	550	500	460	430	400	380	330	250
1/2	18000	880	790	710	670	640	590	540	500	470	440	390	290
	20000	980	870	790	750	710	650	600	560	520	490	440	330
5/8	18000	1380	1230	1100	1050	1000	920	850	790	740	690	610	460
	20000	1530	1360	1230	1170	1120	1020	940	880	820	770	680	510



$$\text{TABLE VALUES (2 LEGS)} = \frac{\text{SHEAR FORCE AT SECTION IN LBS.}}{\text{LEVER ARM.}} = \frac{S}{a}$$

SQUARE TIED COLUMNS. SAFE AXIAL LOAD IN KIPS & PERCENTAGES OF VERTICAL STEEL

$P = cA + c_1 A_c$ C.P. 114 (1948). ROUND MILD STEEL BARS $c_1 = 18000$ p.s.i.

SIZE OF COLUMN (in)		6×6	7½×7½	8×8	9×9	10×10	10½×10½	11×11	12×12
VERTICAL STEEL		DIRECT COMPRESSION STRESS IN p.s.i.							
NUMBER & DIAM	A_c sq. in	760 950 1140	760 950 1140	760 950 1140	760 950 1140	760 950 1140	760 950 1140	760 950 1140	760 950 1140
4 - ½	0·79	40 47 54 2·18	56 66 77 1·40	62 74 86 1·22	75 90 105 0·97				
4 - ⅝	1·23	48 55 61 3·42	64 74 84 2·19	69 81 93 1·92	82 97 113 1·52	97 116 134 1·23	105 125 146 1·11	113 135 158 1·02	130 157 184 0·86
4 - ¾	1·77	57 64 70 4·90	73 83 94 3·15	79 91 102 2·76	92 107 122 2·17	106 125 143 1·77	114 135 155 1·60	122 145 167 1·46	140 167 194 1·22
4 - ⅞	2·40	68 75 81 6·66	84 94 104 4·27	90 101 113 3·77	103 117 132 2·97	117 136 154 2·40	125 145 166 2·17	133 155 178 1·99	150 177 204 1·68
4 - 1	3·14		96 107 117 5·58	102 114 126 4·90	115 130 145 3·87	130 148 166 3·14	138 158 178 2·84	146 168 190 2·58	163 190 217 2·17
4 - 1⅛	3 98		111 121 131 7·08	117 128 140 6·22	130 144 159 4·90	144 162 181 3·98	152 172 192 3·60	160 182 205 3·28	178 204 231 2·75
4 - 1¼	4 91				146 160 175 6·06	160 178 196 4·91	168 188 208 4·44	176 198 220 4·07	194 220 247 3·41
4 - 1⅜	5 94					178 196 214 5·94	186 206 225 5·37	194 216 238 4·92	211 238 264 4·13
4 - 1½	7·07						205 225 244 6·40	213 235 257 5·85	231 257 283 4·92

SPLICES IN VERTICAL REINFORCEMENT 24 DIAMETERS

4 BAR COLUMNS CONTINUED.

SIZE OF COLUMN IN.		13 × 13	13½ × 13½	14 × 14	15 × 15	16 × 16	17 × 17	18 × 18
VERTICAL STEEL		DIRECT COMPRESSION STRESS IN p.s.i.						
NUMBER & DIAM	A_c sq. in	760 950 1140	760 950 1140	760 950 1140	760 950 1140	760 950 1140	760 950 1140	760 950 1140
4-¾	1·77	159 190 222 1·04	169 203 237 0·97	179 216 253 0·90				
4-⅞	2·40	169 201 233 1·42	179 214 248 1·32	190 227 264 1·23	212 254 297 1·07	236 284 332 0·94		
4-1	3·14	182 214 245 1·86	192 226 260 1·72	203 239 276 1·60	225 267 309 1·39	248 296 344 1·22	273 328 382 1·08	300 361 422 0·97
4-1⅛	3·98	197 228 259 2·34	207 241 274 2·18	217 254 290 2·02	239 281 323 1·77	263 311 359 1·55	288 342 396 1·37	314 375 436 1·22
4-1¼	4·91	213 244 275 2·90	223 256 290 2·70	233 270 306 2·50	255 297 339 2·18	279 327 374 1·92	304 358 412 1·70	330 391 452 1·52
4-1⅜	5·94	230 261 292 3·52	241 274 308 3·26	251 287 323 3·03	273 315 356 2·64	297 344 392 2·32	322 375 429 2·05	348 409 469 1·83
4-1½	7·07	250 281 311 4·18	260 293 327 3·88	270 306 342 3·61	292 334 375 3·14	316 363 411 2·76	341 395 448 2·45	368 428 488 2·18

SHORT COLUMNS:- UNSUPPORTED LENGTH IS NOT GREATER THAN FIFTEEN TIMES THE LEAST DIMENSION.
DIAMETER OF LATERAL TIES SHALL NOT BE LESS THAN ¼ THE DIAM OF THE MAIN BARS & IN NO CASE LESS THAN 3/16"
SPACING OF LATERAL TIES SHALL BE NOT MORE THAN THE LEAST OF:-

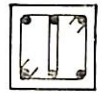
1. LEAST LATERAL DIMENSION OF COLUMN.
2. 12 × DIAM OF THE SMALLEST LONGITUDINAL BAR.
3. TWELVE INCHES.

SQUARE TIED COLUMNS. SAFE AXIAL LOAD IN KIPS & PERCENTAGES OF VERTICAL STEEL

$P = cA + c_1 A_c$ CP 114 (1948) ROUND MILD STEEL BARS $c_1 = 18000$ p.s.i.

SIZE OF COLUMN IN.		12 × 12	13 × 13	13½ × 13½	14 × 14	15 × 15	16 × 16	17 × 17
VERTICAL STEEL		DIRECT COMPRESSION STRESS IN p.s.i.						
NUMBER & DIAM.	A_c sq. in.	760 950 1140	760 950 1140	760 950 1140	760 950 1140	760 950 1140	760 950 1140	760 950 1140
6-½	1·18	129 156 184 0·82						
6-⅝	1·84	141 168 195 1·28	160 192 223 1·09	170 204 238 1·01	180 217 254 0·94	202 245 287 0·82		
6-¾	2·65	155 182 208 1·84	174 205 237 1·57	184 218 252 1·45	194 231 268 1·35	216 259 301 1·18	240 288 336 1·03	265 319 374 0·92
6-⅞	3·61	171 198 225 2·50	190 222 253 2·13	200 234 268 1·98	211 247 284 1·84	233 275 317 1·60	256 304 352 1·41	281 336 390 1·25
6-1	4·71	190 217 243 3·27	209 240 272 2·79	219 253 287 2·59	230 266 302 2·40	252 294 336 2·10	275 323 371 1·84	300 354 408 1·63
6-1⅛	5·96	212 238 264 4·14	231 262 293 3·53	241 274 308 3·28	251 287 324 3·04	273 315 357 2·65	297 344 392 2·33	322 376 430 2·06
6-1¼	7·36		255 286 316 4·35	265 298 331 4·04	275 311 347 3·75	297 339 380 3·27	321 368 416 2·87	346 400 453 2·55
6-1⅜	8·91					324 365 406 3·96	348 395 442 3·48	373 426 479 3·09
6-1½	10·60					353 394 435 4·71	377 424 470 4·14	402 455 508 3·67

SPLICES IN VERTICAL REINFORCEMENT 24 DIAMETERS



6 BAR COLUMNS CONTINUED.

SIZE OF COLUMN IN.		18 × 18	19 × 19	20 × 20	21 × 21	22 × 22	23 × 23	24 × 24
VERTICAL STEEL		DIRECT COMPRESSION STRESS IN p.s.i.						
NUMBER & DIAM.	A_c sq.in.	760 950 1140	760 950 1140	760 950 1140	760 950 1140	760 950 1140	760 950 1140	760 950 1140
6-3/4	2·65	292 353 414 0·82						
6-7/8	3·61	308 369 430 1·11	336 404 472 1·00	366 441 516 0·90	397 480 563 0·82			
6-1	4·71	327 388 448 1·45	355 423 491 1·31	385 460 535 1·18	416 499 582 1·07	449 540 631 0·97	483 582 682 0·89	519 627 736 0·82
6-1⅛	5·96	349 409 469 1·84	377 444 512 1·65	406 481 556 1·49	438 520 603 1·35	470 561 652 1·23	504 604 703 1·13	540 648 757 1·04
6-1¼	7·36	373 433 493 2·27	401 468 535 2·04	430 505 580 1·84	462 544 627 1·67	494 585 675 1·52	529 628 727 1·39	564 672 780 1·28
6-1⅜	8·91	399 459 519 2·75	428 494 561 2·47	457 532 606 2·23	488 570 653 2·02	521 611 702 1·84	555 654 753 1·68	591 699 806 1·55
6-1½	10·60	429 488 548 3·27	457 523 590 2·94	486 560 634 2·65	518 599 681 2·40	550 640 730 2·19	584 683 781 2·00	620 728 835 1·84

SHORT COLUMNS:- UNSUPPORTED LENGTH IS NOT GREATER THAN FIFTEEN TIMES THE LEAST DIMENSION

DIAMETER OF LATERAL TIES SHALL NOT BE LESS THAN ¼ THE DIAM. OF THE MAIN BARS & IN NO CASE LESS THAN 3/16"

SPACING OF LATERAL TIES SHALL BE NOT MORE THAN THE LEAST OF :—

1. LEAST LATERAL DIMENSION OF COLUMN.
2. 12 × DIAM OF THE SMALLEST LONGITUDINAL BAR.
3. TWELVE INCHES.

SQUARE TIED COLUMNS. SAFE AXIAL LOAD IN KIPS & PERCENTAGES OF VERTICAL STEEL

$P = cA + c_1 A_c$ CP.114.(1948). ROUND MILD STEEL BARS $c_1 = 18000$ psi.

SIZE OF COLUMN IN.		12 × 12	13 × 13	13½ × 13½	14 × 14	15 × 15	16 × 16	17 × 17
VERTICAL STEEL		DIRECT COMPRESSION STRESS IN p.s.i						
NUMBER & DIAM.	A_c sq. in.	760 950 1140	760 950 1140	760 950 1140	760 950 1140	760 950 1140	760 950 1140	760 950 1140
8-½	1·57	136 163 190 1·09	155 187 219 0·93	165 200 234 0·86	176 213 250 0·80			
8-⅝	2·45	151 178 205 1·70	170 202 234 1·45	180 215 249 1·34	191 228 264 1·25	213 255 297 1·09	236 285 333 0·96	
8-¾	3·53	170 197 223 2·45	189 220 252 2·10	199 233 267 1·94	209 246 283 1·80	231 274 316 1·57	255 303 351 1 38	280 334 389 1·23
8-⅞	4·81	192 218 245 3·34	211 242 273 2·85	221 255 288 2·64	231 268 304 2·45	254 295 337 2·14	277 325 373 1·88	302 356 410 1·67
8-1	6·28	217 243 270 4·35	236 267 298 3·72	246 280 313 3·45	257 293 328 3·20	279 320 362 2·79	302 350 397 2·44	328 381 435 2·17
8-1⅛	7·95	2 46 272 298 5·52	265 296 326 4·70	275 308 341 4·36	286 321 357 4·06	308 349 390 3·53	331 378 425 3·10	356 410 463 2·75
8-1¼	9·82		297 328 358 5·80	307 340 373 5·40	318 353 389 5 01	340 381 422 4·36	363 410 457 3·84	389 442 495 3 40
8-1⅜	11·88					375 416 456 5·28	399 445 492 4·64	424 477 529 4·11
8-1½	14 14					414 454 495 6 29	438 484 530 5 52	463 515 567 4·89

SPLICES IN VERTICAL REINFORCEMENT 24 DIAMETERS

B BAR COLUMNS CONTINUED.

SIZE OF COLUMN IN.		18 × 18	19 × 19	20 × 20	21 × 21	22 × 22	23 × 23	24 × 24
VERTICAL STEEL		DIRECT COMPRESSION STRESS IN p.s.i.						
NUMBER & DIAM.	A_c Sq in	760 950 1140	760 950 1140	760 950 1140	760 950 1140	760 950 1140	760 950 1140	760 950 1140
8-3/4	3·53	307 368 428 1·09	335 403 471 0·98	365 440 515 0·88	396 479 562 0·80			
8-7/8	4·81	329 389 450 1·49	357 425 492 1·33	387 462 537 1·20	418 501 583 1·09	450 541 632 0·99	485 584 684 0·91	520 629 737 0·83
8-1	6·28	354 414 475 1·94	382 450 517 1·74	412 487 561 1·57	443 526 608 1·43	476 566 657 1·30	510 609 709 1·19	546 654 762 1·09
8-1⅛	7·95	383 443 503 2·45	411 478 545 2·20	441 515 590 1·99	472 554 636 1·80	504 595 685 1·64	539 638 737 1·50	574 682 790 1·38
8-1¼	9·82	415 474 534 3·02	443 510 577 2·72	473 547 621 2·45	504 586 668 2·22	537 627 717 2·03	571 670 768 1·86	607 714 822 1·70
8-1⅜	11·88	451 510 569 3·67	479 545 611 3·30	508 582 656 2·97	540 621 703 2·70	572 662 752 2·46	606 705 803 2·24	642 749 857 2·06
8-1½	14·14	490 548 607 4·36	518 584 650 3·92	547 621 694 3·53	579 660 741 3·21	611 700 790 2·92	645 743 841 2·67	681 788 895 2·46

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9. Valley Angle Chart for Hoppers and Chutes
10. Shafts up to $5\frac{1}{2}$ inch diameter, subjected to Twisting and Combined Bending and Twisting.
11. Shafts, $5\frac{3}{4}$ to 26 inch diameter, subjected to Twisting and Combined Bending and Twisting.
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14. Spiral Springs (Compression).
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16. ,, ,, (Plate Clutches).
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20. Referred Mean Pressure Cut-Off, etc.
21. Particulars for Balata Belt Drives.
22. $\frac{7}{8}$" Square Duralumin Tubes as Struts.
23. 1" ,, ,, ,, ,,
24. $\frac{3}{4}$" Square Steel Tubes as Struts (30 ton yield).
25. $\frac{7}{8}$" ,, ,, ,, (30 ton yield).
26. 1" ,, ,, ,, (30 ton yield).
27. $\frac{3}{4}$" ,, ,, ,, (40 ton yield).
28. $\frac{7}{8}$" ,, ,, ,, (40 ton yield).
29. 1" ,, ,, ,, (40 ton yield).
30. Moments of Inertia of Built-up Sections (Tables).
31. Moments of Inertia of Built-up Sections (Instructions and Examples). } Connected.
34. Capacity and Speed Chart for Troughed Band Conveyors.
35. Screw Propeller Design (Sheet 1, Diameter Chart).
36. ,, ,, ,, (Sheet 2, Pitch Chart). } Connected.
37. ,, ,, ,, (Sheet 3, Notes & Examples).
38. Open Coil Conical Springs.
39. Close Coil Conical Springs.
40. Trajectory Described by Belt Conveyors (Revised, 1949).
41. Metric Equivalents.
42. Useful Conversion Factors.
43. Torsion of Non-Circular Shafts.
44. Railway Vehicles on Curves.
46. Coned Plate Development.
47. Solution of Triangles (Sheet 1, Right Angles).
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49. Relation between Length, Linear Movement and Angular Movement of Lever (Diagram and Notes).
50. ,, ,, ,, ,, ,, (Chart).
51. Helix Angle and Efficiency of Screws and Worms.
52. Approximate Radius of Gyration of Various Sections.

53. Helical Spring Graphs (Round Wire).
54. ,, ,, ,, (Round Wire). } Connected.
55. ,, ,, ,, (Square Wire).
56. Relative Value of Welds to Rivets.
58. Graphs for Strength of Rectangular Flat Plates of Uniform Thickness.
59. ,, Deflection ,, ,, ,, ,, ,,
61. Deflection of Leaf Spring.
62. Strength of Leaf Spring.
63. Chart Showing Relationship of Various Hardness Tests.
64. Shaft Horse-Power and Proportions of Worm Gear.
65. Ring with Uniform Internal Load (Tangential Strain) } Connected.
66. ,, ,, ,, ,, (Tangential Stress)
67. Hub Pressed on to Steel Shaft. (Maximum Tangential Stress at Bore of Hub).
68. Hub Pressed on to Steel Shaft. (Radial Gripping Pressure between Hub and Shaft).
69. Rotating Disc (Steel) Tangential Strain. } Connected.
70. ,, ,, ,, Stress.
71a. Ring with Uniform External Load, Tangential Strain. } Connected.
72. ,, ,, ,, ,, ,, Stress.
73. Viscosity Temperature Chart for Converting Commercial to Absolute Viscosities. } Connected.
74. Journal Friction on Bearings.
75. Ring Oil Bearings.
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79. Delivery of Water in Pipes for a Given Head.
80. (See No. 105).
81. Involute Toothed Gearing Chart.
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92. Pressure on Sides of Bunker.
93-4-5-6-7. Rolled Steel Sections.
98-9-100. Boiler Safety Valves.
102. Pressure Required for Blanking and Piercing.
103. Punch and Die Clearances for Blanking and Piercing.
104. Nomograph for Valley Angles of Hoppers and Chutes.
105. Permissible Working Stresses in Mild Steel Struts with B.S. 449, 1948.
106. Compound Cylinder (Similar Material) Radial Pressure of Common Diameter (D1).
107. True Angles for Pipe Bends.
108. Development of Spiral Chutes.

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